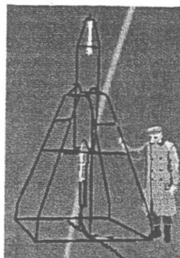


X-ray Polarisation Measurements with a Micro-pattern Gas Polarimeter

J.E. Hill[a,b], J.K. Black[a,c], P. Deines-Jones[a], K. Jahoda[a], R Bellazzini[d], A. Brez[d], E. Costa[e], P. Kaaret[f], M. Minuti[d], G. Spandre[d], J.H. Swank[a]

[a]NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA, [b]Universities Space Research Association, Columbia, MD, 21044, USA, [c]Forbin Scientific, Code 662, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA , [d]INFN sez.Pisa, Largo B. Pontecorvo, 3 I-56127 Pisa, Italy, [e]Department Istituto di Astrofisica Spaziale e Fisica Cosmica - INAF, Via Fosso del Cavaliere, 100 I-00133 Roma, Italy, [f]Department of Physics & Astronomy Department, University of Iowa, USA

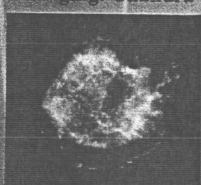
The benefits of Astrophysical X-ray polarisation measurements have been discussed in the literature for decades and with respect to a variety of detectors. Despite this, a dedicated polarimeter for the measurement of Astrophysical sources has not flown since the 1970's, when the definitive measurement of the Crab Nebula was made. More recently, an indirect measurement of the polarisation of two gamma-ray bursts has been extracted from BATSE data, re-emphasising the importance of polarisation measurements in constraining a physical model.

We describe a sensitive, and extremely versatile, photoelectric polarimeter using a micro-pattern gas detector, with an 80 um pixel ASIC anode, to image the primary photoelectron track. The detector can be optimised to a preferred energy range between 1 keV and 50 keV. We present measurements of polarised 4.5 keV X-rays and unpolarised 6 keV X-rays obtained with a proto-type detector using Carbon Dioxide gas.

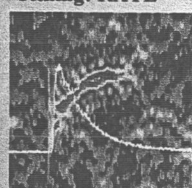
This work was supported, in part, by a NASA Explorer Program Technology Grant.

Polarimetry - The Missing Link?

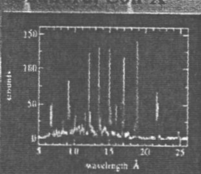
Imaging: Chandra



Timing: RXTE



Spectroscopy: XMM Chandra, Con-X



Polarimetry?

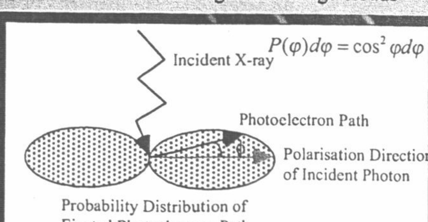
- How important is particle acceleration in supernova remnants?
- How is energy extracted from gas flowing into Black holes?
- What happens to gas near accreting Neutron Stars?

The degree, direction and energy dependence of the polarisation provides a measure of the non-thermal electron distribution and possible magnetic field configurations

How does it work?

The photoelectron is ejected with a $\cos^2\theta\sin^2\phi$ distribution aligned with the E-field of the incident X-ray

The photoelectron looses its energy with elastic and inelastic collisions creating small charge clouds



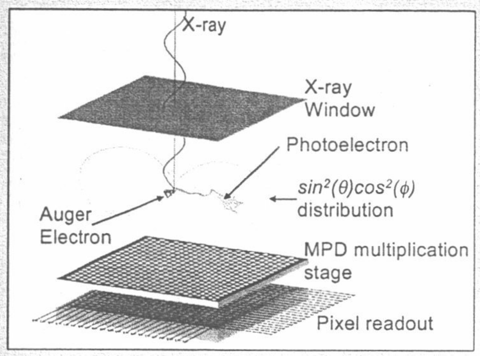
Fit function to the angular distribution:

$$N(\phi) = A + B\cos^2(\phi + \phi_{pol})$$

Polarisation Sensitivity or Modulation Factor, μ:

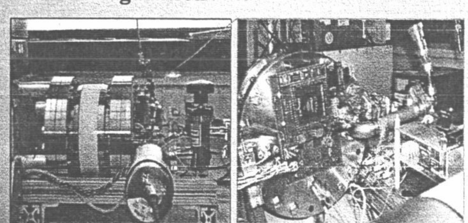
$$\mu = \frac{N_{max} - N_{min}}{N_{max} + N_{min}} = \frac{B}{2A + B}$$

A Micro-pattern Gas Polarimeter

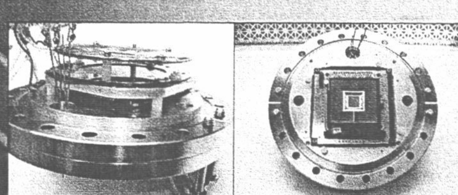


- X-ray interacts in the gas
- Photoelectron creates an electron cloud
- Electron cloud drifts to cathode
- Electron multiplication occurs between cathode and anode
- Charge finally collected at the pixel readout

Test Configuration



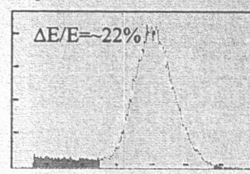
- An FPGA controls the ASIC and the ADC
- Allows a programmable window mode - preserves telemetry
- Real-time pedestal subtraction (bias subtraction)
- Event-by-event centroid calculation



- 80 μm pitch ASIC (right) (building 50 μm pitch)
- 150 μm pitch meshes at 180 μm separation (left)

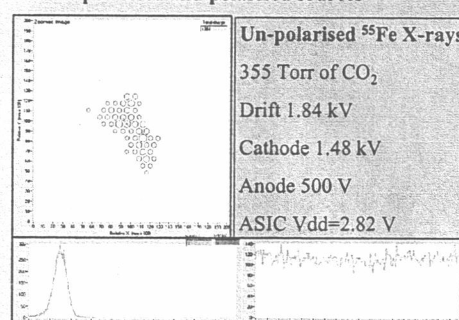
Preliminary Results

Spectral Resolution



Cathode ^{55}Fe Spectrum
Proportional Counter Resolution

Photoelectron tracks and angular distributions for un-polarised and polarised sources



Un-polarised ^{55}Fe X-rays

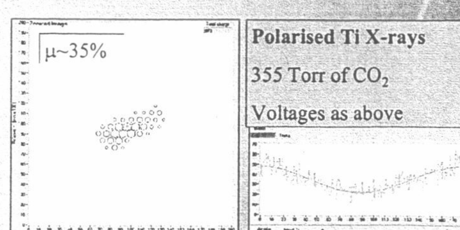
355 Torr of CO_2

Drift 1.84 kV

Cathode 1.48 kV

Anode 500 V

ASIC Vdd=2.82 V



Polarised Ti X-rays

355 Torr of CO_2

Voltages as above

Further Work

- Determine modulation factor for current configuration
- Verify results against the simulator
- For a given energy band
  - Characterise different gases
  - Optimise pressure
- Optimise voltages for resolution and sensitivity
- Test meshes with 80 μm pitch
- Characterise ASIC operation
- Quantify Quantum Efficiency for optimum polarisation sensitivity